Land use effects of road pricing – a literature review

Michael Löchl, ETHZ

Conference paper STRC 2006

STRC

6th Swiss Transport Research Conference
Monte Verità / Ascona, March 15. – 17. 2006

Land use effects of road pricing – a literature review

Michael Löchl
Institute for Transport Planning
and Systems (IVT)
ETH Zurich
Zurich

Phone: +41 – 44 – 633 62 58
Fax: +41 – 44 – 633 10 57
email: loechl@ivt.baug.ethz.ch

March 2006

Abstract

Road pricing is often mentioned as an effective measure for sustainable transport in metropolitan areas. A broad body of literature about this topic is available, focusing mainly on short-term transport, economic and acceptability aspects of pricing policies. The spatial aspects of road pricing however have received much less attention so far, although literature begins to emerge. The paper aims to summarize the literature available to date. It considers both theoretic and modelling work as well as practical experiences particularly dealing with various kinds of inner city road pricing.

Keywords

Road pricing– congestion charging – land use effects – relocation

Source of picture on cover page: http://www.no-congestion-charge.com/

1. Introduction

Most proponents of road pricing base their support on its demonstrated efficiency when compared to an unpriced and congested situation. Nevertheless it remained unpopular for most politicians and voters for a long time, so that the number of working examples has been rather narrow so far. Thanks to continued increasing congestion problems, particularly in agglomerations, successful implementations elsewhere, and shifts in political attitudes, there is increasing interest in Switzerland and abroad.

A broad body of literature about this topic is available, focusing mainly on short-term transport, economic (e.g. overview in Button, 2004; Santos, 2004, in particular) and acceptability aspects (e.g. Schade and Schlag, 2003) of pricing policies. The geographical aspects of road pricing however have received much less attention so far, although literature begins to emerge. The paper aims to summarize the international literature available so far. It considers both theoretical and modelling work as well as practical experiences.

Much of the discussion and modelling efforts of road pricing has looked at the effects that pricing would have on trip generation, the choice of route, mode and departure time. However, such analysis is largely based on the assumptions that travel origins and destinations are fixed. In fact, road pricing will also have impacts on trip destination choice and long term effects on both residential and employment location choice. Consequently, land use changes can be expected. De Palma, Lindsey and Niskanen note in a recent paper (de Palma, Linsey, Niskanen, 2006, 157) that since the stakes involved in the introduction of major urban transport pricing reforms are so large, the extra effort required to consider land use effects besides all transport effects appears to be justified and worthwhile.

The following section 1.1 gives definitions about land use impacts of transport policies and an overview of road pricing types. Section 2 summarizes theories and arguments given in the literature about possible spatial effects of road pricing. They are not based on empirical data and therefore hypothetical. The following section 3 describes the applied research to investigate land use effects. The found approaches can be subdivided into empirical analytical ex ante studies (section 3.1), various modelling approaches (section 3.2) and reports about ex post monitoring and analysis after an introduction of road pricing (section 3.3).

1.1 Definitions and focus

Land use impacts of transport infrastructure and policy are changes in the spatial distribution and the density of functions (housing, agricultural, industrial and commercial use, recreation and leisure as well as environment) and its spatial prerequisites, derived from the distribution

of environmental qualities and constraints, accessibility quality, capacity and others. (Bundesamt für Raumentwicklung, 2003, 13). Spatial distribution relies on the location choice of economic agents such as firm and households as well as building law and supply. However, the focus in this paper is on land use impacts of road pricing. Particularly location effects of housing and firms in form of employment are considered in this paper as most available literature does. Some specific experiences are also given for the retail sector.

There are several kinds of road pricing applied worldwide (see Table 1). In order to narrow the topic, road pricing will be discussed here in an urban context, therefore mainly considering area and cordon pricing in inner cities.

Table 1 Road pricing types

		Gained eligibility for paying	Application
Passage pricing	Object pricing	Using bridges, tunnels or particular sections of a road	Bridges: Öresund; tunnel: Gr. St. Bernard, road sections: Lyon Peripherique, Rostock
	Cordon pricing	Crossing the cordon limit in or out	Oslo, Trondheim, Stockholm
Motorway pricing	Time dependent	Using a motorway for the paid period	Car vignette in Austria and Switzerland
	Distance or route dependent	Using a motorway section	France, Italy, Spain, Austria (heavy vehicles)
Area pricing	Area licensing	Using all streets within priced area during the paid period	London
	Area charging	Distance dependent fee for use of all streets within charged area	Swiss Heavy Vehicle Fee
	Differentiated area charging	Distance or route dependent, differentiated by street type within charged area	Not introduced yet
Value pricing		Using separated lines on motorways	Express line (HOT-lanes) SR91 Los Angeles, several Fast Track project in the US

Source: Rapp 2004

2. Theories and arguments

Road pricing can have noteworthy effects at many levels of the behavioural hierarchy (e.g. Deakin et al. 1996, 3-2f): short term and tactically such as route choice, time of travel, mode choice, destination choice, trip frequency and chaining as well as long term and strategically such as destination choice, car ownership, public transport pass ownership, residential and employment location choice, residential and commercial construction.

The long term decisions have again implications on the short term ones as Tillema, Ettema and van Wee (2005, 1) describe. Relocations imply changes in trip patterns and distances, which in turn have an effect on congestion level and the impacts of road pricing. On the other hand, relocation may imply that alternative modes become more or less attractive, leading to mode changes, which also affect congestion. Additional changes in residential and work locations may also have an impact on the real estate market, such as for example the need for more or less houses and offices at particular places and/or changing rent prices.

Eliasson and Mattsson (2001, 429) describe the location effects as ambiguous. According to them, the effects depend on congestion levels in the initial situation and how fast increasing travel costs will cause travel times to fall. The effects would also depend on how the many complex interactions between the locations of different uses exactly work out and on what options the actors have to neutralise the effects of road pricing. Moreover, they state that it is not clear how much of the congestion-decreasing effects of road pricing will be counteracted by the possibly more dispersed location pattern, and the increased number and length of trips caused by the decreased travel times.

Location choice theory and the role of transport costs

Transport is given an essential role by the classic location choice theory in both macro and micro approaches (von Thünen 1921; Weber, 1909; Lösch 1940; Isard, 1956; Alonso 1964; Romanos, 1976). Scale and other agglomeration economies make it advantageous to concentrate production in certain central places where goods and services are produced for their inhabitants and those of the surrounding country-side. Therefore, firms locate in the place which enables them to minimize the total cost of transport, taking into account both the supply of inputs, including labour, and the delivery of outputs. According to classic residential location theory, households rather make trade offs among accessibility, rent costs and other needs (Alonso, 1964; Romanos, 1976). Therefore, transport is considered to be less crucial than in classical firm location choice theory, but is still an important determinant.

However, those theoretical approaches neglect the decreasing role of transport costs, ubiquitous availability of infrastructures nowadays in many regions and differing levels and spatial distribution of demand given. Both firms and households with different characteristics, cost functions and transport needs respectively might be affected differently by an increase of transport costs through road pricing. As Flyvbjerg, Bruzelius and Rothengatter (2003, 71) note, transport costs are a relatively small component of the final price of goods, but are largely depending on the branch. They found values anything between 1 to 7 percent. Those figures are in line with other studies, when only considering pure transport and not logistic costs (Laaser, 2006). Consequently, it was found in a numerical modelling exercise of firm location choice in discrete space that variations of transport costs have only a very limited effect on the heterogeneity of the equilibrium distribution of firms (Sanner, 2004, 19).

However, Vickerman (2005, 7) concludes, that the changing economic structure implies a changing significance of transport costs, in terms of both direct costs for inputs and outputs and the costs of commuting by workers. Since firms in sectors such as financial services, tourism and retail distribution are highly competitive on a global scale and highly footloose, he assumes that they may be extremely sensitive to differences in costs occasioned by different patterns of local transport provision such as road pricing.

Varying spatial effects

For road pricing measures with a seamless country-wide pricing, research of travel costs elasticities (i.e. de Jong and Gunn, 2001) might be taken into account, but this can't be applied to any area or cordon pricing. Those schemes will have varying spatial effects depending on the location and even on time. For the cordon toll case in Oslo (Larsen, 1995, 196), it has been stated that the population might have the tendency to live, work and do shopping either inside or outside the cordons in the long term. At the point of its publication (6 years after the introduction), the author suggest that locations very close to the cordon boundaries might become less attractive and property prices should consequently be affected in the long run. However, the effects are assumed to be rather modest since the costs involved for car drivers are relatively low.

Theoretic analytical studies

Theoretic analytical studies imply limited research concerning theoretic spatial effects of road pricing on trip and location changes. The described effects (Deakin 1994; Deakin et al. 1996; Larsen, 1995; Komanoff 1997; Banister 2002; Sanner 2004) seem logical but are not based on empirical data and therefore hypothetical. Nevertheless, the literature seems to be unanimous that the many varieties of spatial configuration, transport infrastructures, travel alternatives and pricing schemes preclude general rules about the land use effects of road pricing. It

becomes clear that each study of land use impacts has to be reviewed by considering the envisaged road pricing measure, pricing scheme and its spatial context.

While some researchers argue that appropriate pricing of transport would lead to more compact cities, other see congestion pricing as a potentially significant centrifugal force in metropolitan development (Levine, Garb, 2002, 181). Neither theory nor research on the relationship between the cost of transportation and urban development provides compelling evidence to support whether road and congestion pricing would have a centralizing or decentralizing effect (National Research Council, 1994, 53). Deakin cites the potential of both directions of effects, and considers a range of adaptive behaviours on the part of travellers/residents, businesses and local government (Deakin 1994, 343ff). Anyway, the question of land use effects is complicated since there are many forces working in opposite directions (Elliasson and Mattsson, 2001, 428).

Particular with regard to any inner city cordon charge, there is considerable concern about the effects on the retail sector, as it forms an important part of an economically healthy and vivid city. Theoretically, the main force towards agglomerated structures of retail shops is the reduction of transaction costs for consumers if retailers are located closely, whilst competition and transport costs work towards dispersed structure (Sanner, 2004, 1).

Impact of the design of road pricing

The land use effects of road pricing are relying highly on their design such as pricing schemes, extent and delimitation of the area in which pricing is applied, and if the road pricing comes with an addition of new road or public transport capacity. Typically, network capacity additions would support suburban development and spread land use in the long run (Gupta, Kalmanje, Kockelmann, 2005). Even without network capacity additions, the fact of travel time decreases as a result of road pricing might have the same effect.

Another important factor, maybe even the most significant determinant, is the way revenue is used as some authors suggest (Komanoff 1997, Levine, Garb, 2002, 181f). For example, using pricing revenues to fund superior transit options could serve to focus development around activity nodes (TCRP 2003, 14-47). Moreover, the possibility of using the revenue to offset price disadvantage of the scheme should not be discounted (Rufolo, Bianco, 1998, 14). Therefore, relocation decisions may be influenced by the type and design of road pricing measure. Finally, it has been suggested elsewhere that other road pricing types such as a flat kilometre charge may especially have an effect on the distribution of people over locations (Tillema, Ettema and van Wee, 2005, 4).

3. Research approaches

The currently available literature on the applied investigation of spatial effects of road pricing is mostly concerned with any kind of area or cordon pricing in inner cities. The reported studies can be subdivided into three general research approaches:

- empiric analytical studies (ex ante and hypothetical)
- modelling approaches, and
- ex post monitoring and analysis (after an actual road pricing introduction).

However, there are few modelling approaches which have been used in ex-post monitoring and analysis. They are described in the latter case.

3.1 Empiric analytical studies (ex ante)

In this section, studies about ex ante investigations before the introduction of a road pricing scheme as well as in-depth interviews and hypothetical stated choice studies are considered. Clearly, the amount of available studies is very limited so far.

Housing/Population

Recent work of Tillema, Ettema and Van Wee (2006) investigates the effect of road pricing on relocation of households by two stated choice surveys in the Netherlands, i.e. they consider both the decision whether or not households relocate and the decision in which location to reside. With respect to the probability of moving, on average 5 percent of the respondents indicated a quite high, high or extremely high probability of moving to another residential location when a road pricing measure would be implemented. The probability of searching for another job was found to be significantly larger with about 13.5 percent. Nevertheless, the majority of those respondents also answered that the chance of changing house or work within 2 years for whatever reason is considerable. Therefore, the actual relocation effect due to road pricing could not be quantified, but it would be certainly lower than the observed percentages.

As regards residential location choice of car commuters confronted with traffic congestion on a regular basis, they found that travel costs are an important factor. They conclude that individuals in general prefer to pay higher housing costs and accept longer travel times in order to avoid (higher) travel costs. Nevertheless, location related factors such as the type of location and the number of bedrooms seem to be important factors in a residential location

choice, too. Another finding is that people with a longer current trip time are less sensitive to both travel time and travel costs.

Businesses/Employment

Whitehead (2002) reports about a project which investigated the processes of economic change that road pricing might cause. 38 in-depth interviews were held with respondents from government, the property development industry, business and academia in a range of major cities in the United Kingdom on a base of various hypothetical road user charging scenarios. Whitehead summarizes that the effects of road pricing on businesses will depend on different causal chains that may apply in different cities depending on city scale and regional competitiveness. Whitehead describes that the economic processes involved depend on the relative impact of negative competitiveness effects (caused by the introduction of charging) versus beneficial amenity effects (caused by reduction in congestion and/or recycling of the revenues into public transport and environmental improvements). Eventually, he identifies three levels of responses:

- First order responses: initial reactions to charging, such as changing route, travel time or mode

- Second order responses: relocation of activities to take advantage of the new accessibility of different modes, or urban quality changes.

- Third order responses: decisions concerning the construction of new floorspace and/or further public-private investment in public transport/urban quality, in response to the demand created from second order responses.

Whitehead (2005, 453) concludes from the survey that the firm location effects will be modest overall, except for those businesses that operate at the margins of profitability and for new business entries.

The Dutch consulting firm MuConsult (2000) carried out an extensive study concerning the spatial effects of pricing policies such as kilometre charge, cordon pricing and parking charge. Tillema, van Wee and Jong (2003b, 7) report that one conclusion is that a considerable part of employees can transfer costs on their employers. Consequently, the incentive to change behaviour is low.

3.2 Modelling approaches

First approaches which take into account land use in road pricing modelling in any way date back to the 60s and 70s (Strotz, 1965; Solow, Vickrey, 1971; Liversey, 1973; Henderson,

1975; Arnott, MacKinnon, 1978). Nevertheless, those early studies were based on rather abstract theoretical models, assuming mostly a monocentric city with all employment located in the Central Business District (CBD) and that all travel is to the CBD and work related. The models were focussing on land rents, optimal land allocation, densities and city size etc. instead of resulting spatial distributions and densities in the urban area because of road pricing. In any case, geographical effects have not been studied in detail.

However, there is more recent literature concerned with modelled geographical aspects of road pricing. These studies are often based on land use-transport (LUT) packages or other sophisticated (choice) models. The latter ones are micro-simulation models at an urban level based on utility-theory, which were particularly developed to study these effects.

Models particularly developed to study spatial road pricing impacts

Anas and Xu (1999) use a generic computable general equilibrium model to study effects of first-best road pricing with and without first-best infrastructure provision in a dispersed and polycentric city. The model is calibrated to replicate typical land use densities. Their main conclusion is that road pricing will have a centralising effect on both residential density and employment. However, they admit that their model does not consider agglomeration economies which might cause employment to concentrate in distinct subcentres. Arnott (1998) use utility functions with linked equations to model effects in a mono-centric city. The results suggest as well that road pricing leads to a more concentrated city as the rent and population density gradients become steeper. But account has to be taken of the possibility of a congestion charge to reallocate the traffic over the peak period. Therefore, Arnott uses a bottleneck model, which involves trip timing decisions but no redistribution of revenues. In this case, the toll has no effect on urban spatial structure. The author concludes that in reality effects presumably lay somewhere in between the results given by both methods. In case the bottleneck model is right, Arnott states that the absence of congestion tolling has probably led to less excessive decentralization of economic activity than was hitherto believed (Arnott 1998, 503). Both of the two mentioned models, however, have not been validated against empirical data.

By another simulation approach, Eliasson and Mattsson (2001) estimate nested logit models based on utility functions and subsequently use these models to determine trip and location effects in a polycentric generic city while the transport system is modelled by a static network equilibrium model. Both object pricing depending on congestion, also called congestion charging, and cordon pricing is considered. The study concludes that based on congestion charging, road pricing makes the city in general less dispersed. However, it is not primarily the city centre that grows denser, but rather the innermost ring of the suburbs, gaining about 2 percent more households and workplaces and about 5 percent more shops and service

establishments at full congestion pricing. The outer suburbs lose on the average about 3 percent of their households and workplaces and 7 percent of their shops and service establishments. With regard to pricing level, the authors note that the main effects occur at relatively low levels of congestion pricing. Above it, there are relatively small further effects. When looking at a cordon pricing, location effects depend strongly on where the toll ring is located. If the area enclosed is large, locations outside the toll ring become less attractive which refers to a centralising effect. Conversely, a small toll ring will cause households, workplaces, shops and service establishments to move outside the ring. However, they conclude that the overall location effects are small in comparison to the effects on the travel pattern.

Land use-transport packages

There are various studies done in the past which analyse land use impacts of area and cordon pricing with large-scale urban models by using available land use transport packages. Recent overviews and descriptions about those available packages can be found in Wegener (2004) and Hunt et al. (2005). Those packages are applied for a broad set of policy impact investigations and are not limited to research land use effects of road pricing schemes. An earlier overview of such simulation results has been done by Whitehead (2005, 455). He particularly considered residential and employment changes in the charged inner city area and outside. His summary has been adjusted and expanded with other studies found (Table 2 in the Annex). The reported results point in the direction of a slight residential centralisation in the city centre while the effects on employment are ambiguous. In four out of ten considerable studies, a decentralisation effect of employment has been estimated. Therefore, at least the residential land use effects seem to be similar with the other modelling approaches described before.

Results from PROPOLIS

Within the EU-funded project PROPOLIS (Lautso et al. 2004) various policies have been tested with different land use-transport simulation packages in eight cities in Europe. One of the various policies tested included an inner city cordon pricing. The charge has been in all cases equal to the value of time for work purpose trips of 20 and 60 minutes. This corresponds to approx. 0.85 € to 2 € resp. 2.50 € to 6 € depending on local/national value of time figures. The physical design of the cordon pricing has been city specific. The population and employment changes 10 years after the hypothetical introduction in 2001 have been predicted. The results by spatial entity are summarized in Table 3 in the Annex. Overall, it can be said, that the observed land use effects have been similar to some degree. There has been a tendency that households move towards the central areas in order to avoid the cordon toll, while employment moves out because of the same reason. However, this isn’t the case for

households in the modelling applications for Naples and Venice and to some degree for Inverness as well, although differing spatial categories from all other applications have to be taken into account there.

Other studies with land use-transport packages

In another study, Spiekermann and Wegener (2005) modelled the impacts of a broad set of land use and transport policy changes in the East Ruhr District with the integrated land use and transport model IRPUD by comparing the reference year 2006 with the prediction for 2030. The applied model builds on the simulation used in the PROPOLIS project, but has been adjusted. In case of the introduction of a city toll of 6 Euro, the model is predicting an increase of inhabitants in the inner city centre of plus 1.6 %, in the outer city area of minus 1% and in the surrounding municipalities of plus 0.5%. Overall, they concluded that changes in transport costs have strong effects on travel behaviour but marginal effects on land use. The reason they state is that a broad potential of the reorganisation of housing and employment location is happening within the available building stock (Spiekermann, Wegener, 2005, 58).

De Palma et al. (2004) report about investigations of land use changes after the introduction of road pricing measures by applying land use-transport models for Oslo (RETRO) and Helsinki (MEPLAN). They do not state any specific residential and employment changes as they are focussing on welfare gains. However, they conclude from their modelling experiences that residents and employers may choose to move away from a cordon ring both inwards and outwards from the city centre, whereas link-based tolling induces them to concentrate towards the centre.

Overall, the conclusions which can be drawn from the found modelling work in the literature are that most models anticipate a residential centralisation while there seems not to be a clear tendency for employment. The reason might be a large dependency on the spatial employment distribution and structure in the initial situation. Nevertheless, all predicted spatial location changes are rather small and the effects might vary from the inner city to the outer rings.

3.3 Ex post monitoring and analysis

It can be expected that the full land use effects occur rather long term after the introduction of a pricing scheme. So far, there is almost no data available about observed spatial responses to road pricing. Nevertheless, since cases of the application of road pricing and its monitoring with regard to land use are increasing, the lack of empirical data about effects is going to diminish slowly. Information becomes available about traffic impacts, people and business attitudes and perceptions as well as changes in number of businesses, turnover, profitability,

employment business turnover, residential location changes and real estate prices after road pricing has been introduced. However, the problem of controlling for external effects beyond road pricing always remains. Any road pricing scheme might come with a whole set of additional measures like the significant improvement of public transport and mitigations for inhabitants. Moreover, the effect of road pricing might be neglected by other processes in the urban economy, which makes it hard to isolate it. In Singapore for example, a first road pricing scheme had been introduced in the inner city in 1975. Amstrong-Wright (1986) reports in 1986, that any impact that the scheme may have had on land values, land use and the environment in Singapore, has been largely eclipsed by other factors in the economy.

Experiences from London

The most prominent recent application is the introduction of congestion charging in London's city centre in February 2003. Since then, Transport for London (TfL) has been monitoring impacts by an extensive research programme in two main ways, through evidence on trends in employment and activity and through regular opinion surveys (Transport for London, 2003, 2004, 2005). In the latest report, TfL concludes that "some sectors within the charging zone have shown better performance than outside the zone. Other sectors have performed worse inside the zone than outside. These differences are all relatively small, and are not consistent between different datasets. It is not possible to be certain what part of these differences (positive or negative) result from the congestion charge" (Transport for London, 2005, 5). Therefore, the impacts seem to be rather neutral. Nevertheless, one has to take into account that land use impacts are rather long term and the duration since the introduction is too short to draw final conclusions.

There is research which investigates impacts of the congestion charging on London's retail sales in detail by applying econometric models (Quddus et al., 2006). One of the used datasets includes weekly sales data for six stores of a retail chain in London, whereas one of the stores is located in the charged zone. The authors found a significant negative impact on sales at this store over a period of about eleven months following the introduction of the charge compared to the other five stores. However, the factor of competition among shops and the spatial redistribution of sales could not be considered in the analysis. A second dataset covering total retail sales in central London[1], did not show a significant downturn because of the charge.

[1] The area coincides with one covered by the London Retail Consortiums's central London Retail Sales index. It includes the congestion charging zone plus the neighbourhoods of Knightsbridge and High Street Kensington. However, central London retail sales is likely to be mainly influenced by sales within the charging zone as Quddus et al. (2006) describe.

This supports suspicion of spatial substitution. Therefore, no congestion charging impact could be found as a whole. Nevertheless, it is still possible that there has been some redistribution of sales from certain areas to other stores within central London (Quddus et al., 2006, 20)

Vickerman (2005, 6) reports about recent experiences in London and Edinburgh, where workers sought to compensate for higher housing prices in the cordon area by longer commuting journeys from more distant areas with lower housing prices. Apparently, those processes even happen before the introduction of any road pricing, as the scheme has been eventually declined in Edinburgh. In the case of London, Vickerman (2005, 11) concludes that the overall pressure of demand was likely to have been much more important than transport costs in determining property rents. Nevertheless, he admits that a fuller investigation of demand-supply conditions in the central London property market would be needed to substantiate this.

Changes in the property market needs to be taken into account as well. The Royal Institute of Chartered Surveyors (RICS) reports in 2004 (Royal Institute of Chartered Surveyors, 2004) that "whilst the introduction of the charge has been remarkable smooth and the overall impact on the residential and office sectors has been broadly neutral or even positive, the retail and leisure sectors do appear to have been adversely affected". One year later, the RICS (Royal Institute of Chartered Surveyors, 2005) confirms that while nine out of ten retailers report some loss of turnover there is almost no impact on moves to relocate beyond the charging zone, land values or rents. Similar results have been reported from Bergen, Oslo and Trondheim (Larsen 1995, 196), where cordon pricing has been introduced in the late 80s and early 90s, although the raised charges are rather small in those Norwegian cities compared to London.

Effects on retail in Trondheim

Particularly for Trondheim, there has been some research about the effects on shopping behaviour after the introduction of road pricing in 1991. A study (Avant Management A/S, 1992) found that 10% of the customers had changed their shopping behaviour by moving their shopping to other destinations or times after the introduction of the cordon pricing as Tretvik (2003, 88) translates. Moreover, while business people located in the city centre had predicted major negative swings in trade prior to the cordon pricing, the Chamber of Commerce of Trondheim concluded from an own ex post survey that there was hardly any effect on trade at all. Anyway, there was a long lasting general trend of growth in areas outside and decline in areas of the cordon. Tretvik (1999) even concludes a general trend line of modest but steady growth in retail sales in real terms inside the cordon since the introduction as he reports in a different publication (Tretvik, 2003, 89).

It is difficult to know to what extent experiences and conclusions drawn from one city can be transferred and generalised to other cities, since the effects depend to a large extent on particular characteristics of a city such as its spatial composition, street network form and capacity, quality of public transport network and so on. Another important factor is certainly the design of the road pricing scheme, particularly the extent of the cordon as some modelling experiences revealed (Elliasson and Mattsson, 2001, 418 and 442).

4. Conclusions

There is no doubt that the spatial effects of road pricing are quite complicated to investigate. This is due to the variety of road pricing policy design alternatives, their interaction with other policies and overlaying processes in the urban economy and the different resulting adaptive behaviours of markets and actors. In this literature review, only inner city area and cordon pricing scheme investigations have been considered. While there are very few ex ante and ex post studies, many more modelling approaches have been found. Nevertheless, neither theory nor applied research seems to provide a general answer to the question, if such pricing schemes in inner city areas will result in more compact or disperse development in view of residential and employment land uses. However, all studies under review suggest the spatial effects of road pricing as marginal overall when modest pricing schemes are applied, although local impacts in some areas might be strong. Therefore, the effects certainly differ depending on spatial structure and other local circumstances. This is why differentiated investigations are necessary in any potential application. Regarding the question of centralising vs. decentralisation, most modelling approaches suggest a centralisation effect at least for residential land use because of any kind of inner city road pricing while the spatial effects on firms differ.

So far, there is only very few empirical data about revealed behaviour available. With new introductions and other present applications with proceeding time durations, this might change. However, the problem of isolating the land use impacts of road pricing from other effects remains somewhat unsolved in all ex post monitoring attempts. Modelling approaches are providing alternatives to this problem since they offer opportunities to better control for other variables and processes. Particularly land use-transport models seem to be appropriate to forecast land use impacts at a relatively high spatial resolution while considering the most important markets and actors with regard to spatial development. Nevertheless, the accuracy of the models has to be proved in the future with observed data from actual road pricing applications.

The thorough evaluation of any road pricing policy requires a careful consideration and analysis of long-term effects of road pricing. This particularly includes shifts in location choices and resulting land use changes as it will also have impacts on future traffic generation and flows in the long run.

5. References

Alonso, W. (1964) *Location and land use – toward a general theory of land rent*, Harvard University Press, Cambridge, Massachusetts.

Anas, A. and R. Xu (1999) Congestion, land use, and job dispersion: a general equilibrium model, *Journal of Urban Economics*, **45** (3) 451-473.

Armstrong, A.T. (1986) Road pricing and user restraint: opportunities and constraints in developing countries, *Transportation Research A*, **20A** (2), 123-127.

Arnott, R.J. (1998) Congestion tolling and urban spatial structure, *Journal of Regional Science*, **38** (3) 495-504.

Arnott, R.J and J.G. MacKinnon (1978) Market and shadow land rents with congestion, *American Economic Review*, **68**, 588-600.

Avant Management A/S (1992) *Handelsundersøkelsen 1992, Trondheim med omkringliggende kommuner*. [The trade inquiry of 1992, Trondheim with surrounding municipalities.]

Banister, D. (2002) The integration of road pricing with land use planning, essay for the second seminar of the *IMPRINT-EUROPE thematic network*: "Implementing reform on transport pricing: identifying mode-specific issues", Brussels, May 2002.

Bell, M., S. Edwards, N. Thorpe, A. Gillespie and P. Healy (2001) *Long-term environmental assessment of city transport policies* – final report to EPSRC on grant GR/K64235, Department of Civil Engineering. Transport Operations Research Group (TORG), University of Newcastle upon Tyne.

Blok, P.M., I.J. Boeckhout, and A.C.P. Verster (1989) *Orienterend onderzoek naar de ruimtelijke effecten van rekening rijden*, Nederlands Economisch Instituut (NEI), Rotterdam, 1-51.

Bundesamt für Raumentwicklung (Hg.) (2003) Räumliche Auswirkungen der Verkehrsinfrastrukturen „Lernen aus der Vergangenheit", Methodologische Vorstudie, Teil II – Arbeitsbericht, Bern.

Button, K. (2004) The rationale for road pricing: standard theory and latest advances, in G. Santos (eds.) *Road pricing: theory and evidence*, 3-25, Elsevier, Oxford.

Centre for Economics and Business Research Ltd. (CEBR) (2001) *The impact of congestion charging on London's main offices and retail locations*, report on behalf of Healey and Baker, London.

Deakin E. (1994) Urban transportation congestion pricing: effects on urban form. Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion, Transportation Research Board, Commission on Behavior and Social Sciences and Education, National Research Council, Special Report **242**, 334-355.

Deakin, E., G. Harvey, R. Pozdena, G. Yarema, et al. (1996) *Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity*

Impacts. Final Report to the California Air Resource Board, the Federal Highway Administration, the Environmental Protection Agency, and the Caltrans. [Retrieved on January 27 2006, from http://www.arb.ca.gov/research/abstracts/92-316.htm]

de Jong, G.C. and H. Gunn (2001) Recent evidence on car cost and time elasticities of travel demand in Europe, *Journal of Transport Economics and Policy*, **35** (2), 137-160.

de Palma, A., K. Kilani, R. Lindsey, P. Moilanen, S. Proost, A. Sen, A. Vold and E. Niskanen (2004) Welfare effects – urban transport, Workpackage 7, revised final version, Project MC-ICAM (Implementation of marginal cost pricing in transport-integrated conceptual and applied model analysis). [Retrieved on February 24 2006, from http://www.strafica.fi/mcicam/handouts/DELIVERABLES/d7-jan4-04.pdf]

de Palma, A., R. Lindsey and E. Niskanen (2006) Policy insights from the urban road pricing case studies, Transport Policy, **13** (2) 149-161.

Grupta, S., Kalmanje, S. and K. Kockelman (2005) Road pricing simulation: traffic, land use and welfare impacts for Austin, Texas, paper presented at *84th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2005.

Eliasson, J. and L.-G. Mattson (2001) Transport and location effects of road pricing: a simulation approach, *Journal of Transport Economics and Policy*, **35** (3), 417-456.

Henderson, J.V. (1975) Congestion and optimum city size, *Journal of Urban Economics*, **2** (2), 48-62.

Hunt, J.D., D.S. Kriger and E.J. Miller (2005) Current operational urban land-use-transport modelling frameworks: a review, *Transport Review*, **25** (3), 329-376.

Jenson, T. (1999) A study of residential and employment location effects of a road price in the Greater Oslo Area (En studie av lokaliserings- og sysselsettingseffekter ved vegprising I Oslo-området). *TØI Report*, **453/1999**, Institute of Transport Economics and the Norwegian Council of Research, Oslo.

Komanoff, Ch. (1997) Environmental consequences of road pricing – a scoping paper for The Energy Foundation. [Retrieved on January 29, 2006, from http://www.tstc.org/reports/ckdraft6.pdf]

Laaser, C.F. (2006) Raumstrukturelle Auswirkungen der LKW-Maut, Vortrag auf dem 4. Verkehrsreform Workshop „Räumliche Wirkungen von nutzerbezogenen Verkehrskosten“ der Vereinigung für Stadt-, Regional- und Landesplanung“, Hofgeismar, Februar 2006. [Retrieved on March 7, 2006, from http://www.srl.de/dateien/dokumente/srlfmv_laaser_2006.pdf]

Larsen, O.I. (1995) The toll cordons in Norway: an overview, *Journal of Transport Geography*, **3** (3), 187-197.

Lautsi, K, K. Spiekermann, M. Wegener, I. Sheppard, Ph. Steadman, A. Martino, R. Domingo and S. Gayda (2004) *Planning and research of policies for land use and transport for increasing urban sustainability (PROPOLIS)*, final report, second edition, project funded by the European Commission under the Energy, Environment and Sustainable Development Thematic Programme of the figth RTD framework programme, Helsinki.

Lian, J.I. and N. Fearnley (2005) The Oslo toll ring and infrastructure investment scheme, paper, *European Transport Conference*, Strassbourg, October 2005.

Livesey, D.A. (1973) Optimum city size: a minimum congestion cost approach, *Journal of Economic Theory*, **6** (2) 144-161.

Lobe, P. and H. Duchateau (1998) Impacts of transport price on mobility and land use in the Brussels area, paper presented at *International Symposium on Technological and Environmental Topics in Transports* – "Externalities in the Urban Transport: Assessing and Reducing the Impacts", Milano, October 1998.

Lösch, A. (1940) *Die räumliche Ordnung der Wirtschaft: eine Untersuchung über Standort, Wirtschaftsgebiete und internationalem Handel*, Fischer, Jena.

Marcial Echenique & Partners Ltd. (1994) *MEPLAN scenario test for London-P670*, final report to the Department of Transport.

Marcial Echenique & Partners Ltd. (1997) Report on effects of motorway tolling test-MEPLAN model of London and South East Region, LASER Phase II., final report to the Department for Transport.

May, A.D., D. Coombe and T. Travers (1996) The London congestion charging research programme – 5: assessment of the impacts, *Traffic Engineering and Control***, 37** (6), 403-409.

May, A.D., R. Liu, S.P. Shepherd and A. Sumalee (2002) The impact of cordon design on the performance of road pricing schemes, Transport Policy, **9** (3), 209-220.

Mills, E.S. and D.M. DeFerranti (1971) Market choices and optimum city size, *American Economic Review*, **61**, 340-345.

MuConsult (2000) Ruimtelijke Effecten Prijsbeleid in Verkeer en Vervoer (Achtergronddocument), Amersfoort.

Quddus, M., A. Carmel and M.G.H. Bell (2006) The impact of the congestion charge on retail: the London experience, paper presented at *85th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2006.

Rapp, M. (2004) Technik des Road Pricing, *tec21*, **49-50**, 7-11.

Romanos, M.C. (1976) *Residential spatial structure*, Lexington Books, Lexington.

Royal Institute of Chartered Surveyors (2004) RICS research into the impact of congestion charging on London property, London.

Royal Institute of Chartered Surveyors (2005) RICS research into the impact of congestion charging on London property, London.

Rufolo, A.M. and M.J. Bianco (1998) The impact of congestion pricing and parking taxes on spatial competition, proceedings of the *Pacific Northwest Regional Economic Conference*, Olympia (WA), May 1998. [Retrieved on January 15, 2006, from http://www.pnrec.org/1998/papers/trufolo.pdf]

Sanner, H. (2004) *Economy vs. history – What does actually determine the distribution of firm's locations in cities?* Volkswirtschaftliche Diskussionsbeiträge, Nr. 67, Wirtschafts- und Sozialwissenschaftliche Fakultät, Universität Potsdam, Potsdam.

Santos, G. (eds.) (2004) *Road pricing: theory and evidence*, Elsevier, Oxford.

Schade, J., B. Schlag (eds.) (2003) *Acceptability of transport pricing strategies,* Elsevier, Oxford.

Solow, R.M. and W.S. Vickrey (1971) Land use in a long narrow city, *Journal of Economic Theory*, **3** (4) 430-447.

Spiekermann, K. und M. Wegener (2005) *Räumliche Szenarien für das östliche Ruhrgebiet, Schlussbericht*, Spiekermann & Wegener Stadt und Regionalforschung, Dortmund.

Still, B.G., A.D. May and A.L. Bristow (1999) The assessment of transport impacts on land use: practical uses in strategic planning, *Transport Policy*, **6** (2), 83-98.

Strotz, R.H. (1965) Urban Transportation Parables, in J. Margolis (eds.) *The public economy of urban communities*, Johns Hopkins Press, Baltimore.

Supernak, J., D. Brownstone, J. Golob, T. Golob, C. Kaschade, C. Kazimi and D. Steffey (2001) *I-15 congestion pricing project monitoring and evaluation services – Phase II year three land use study*. San Diego Association of Governments. Prepared by San Diego State University Foundation, San Diego.

TCRP (2003) *Road value pricing – traveller response to transportation system changes*, TCRP Report 95, Transportation Research Board, Washington D.C..

Tillema, T. and B. van Wee (2002) Pricing policies: a spatial perspective, contribution to MD-PIT meeting in Amsterdam, Utrecht, September 2002.

Tillema, T., B. van Wee and T. de Jong (2003a) *Road pricing and accessibility: a review of measures and an application for the Utrecht region*, paper presented at the NECTAR conference No.7, June 2003, Umeå (Sweden).

Tillema, T., B. van Wee and T. de Jong (2003b) *Road pricing from a geographical perspective: a literature review and implications for research into accessibility*, paper presented at the 43rd ERSA Congress, August 2003, Jyväskylä (Finland).

Tillema, T., D. Ettema and B. van Wee (2006) *Road pricing and (re)location decisions of households*, proceedings of the 85th TRB Annual Meeting, Washington D.C..

Transport for London (2003) *Congestion charging 6 months on*, London.

Transport for London (2004) Congestion charging: Impacts monitoring – Second annual report, London.

Transport for London (2005) Congestion charging: Impacts monitoring – Third annual report, London.

Transport Initiative Edinburgh Ltd. (2004) The integrated transport initiative for Edinburgh and South East Scotland, proposed congestion charging scheme.

Tretvik, T. (2003) Urban road pricing in Norway: public acceptability and travel behaviour, in J. Schade and B. Schlag (eds.) *Acceptability of transport pricing strategies*, 77-92, Elsevier, Oxford.

Tretvik, T. (1999) The EUROPRICE project: the Trondheim toll ring and the effects on retailing, *SINTEF Memo N-12/99*, SINTEF, Trondheim.

Vickerman, R. (2005) Evaluating the wider economic impacts of congestion charging schemes: the limitations of conventional modelling approaches, paper for 45th ERSA Congress, Amsterdam, August 2005.

Von Thünen, J.H. (1921) *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*, Neud, Jena.

Wegener, M. (2004) Overview of land use transport models, in D.A. Hensher, K.J. Button, K.E. Haynes and P.R. Stopher (eds.) *Handbook of transport geography and spatial systems*, 127-146, Elsevier, Oxford.

Whitehead, T. (2002) Road user charging and business performance: identifying the processes of economic change, *Transport Policy*, **9** (3), 221-240.

Whitehead, T. (2005) Transport charging interventions and economic activity, *Transport Policy*, **12** (5) 451-463.

Annex

Table 2 Integrated land use and transport simulation results with regard to land use effects of inner city cordon pricing

City: scheme (prediction period)[1]	Source	Land use-transport interaction modelling package	Conclusions
London: road user charges	Marcial Echenique & Partners (1994)	LASER (MEPLAN-based)	Trend toward minor commercial and residential centralisation depending on charge level and hypothecation; under low charge with no hypothecation +1.0% to 7.0% for high income households and +2.0 to 4.0% for employment, magnitudes of other scenarios not reported (all information from Whitehead, 2005)
London: cordon pricing for inner city area	May, Coombe, Travers (1996)	LASER (MEPLAN-based)	Marginal changes with residential suburbanisation (-0.2%) and commercial centralisation (+1.0%); (all information from Whitehead, 2005)
London: motorway pricing	Marcial Echenique & Partners (1997)	LASER (MEPLAN-based)	Slight (<1.0%) residential decentralisation and reinforcement of employment but at the expense of Outer London and M25 rim; (all information from Whitehead, 2005)
Brussels: cordon pricing for the whole city region of 7.43 Euro[2]	Lobe, Duchateau (1998)	TRANUS	Population change between -2% and +4% and third sector employment changes between -8% and +1% in the region depending on choosen scenario; prediction period unknown
Edinburgh: cordon pricing for the inner city area of 2.20 Euro (1991-2011)	Still, May, Bristow (1999)	DELTA/START and LUCI	Slight residential centralisation (+0.2%) and employment decentralisation (-5.5 to -7.0%)
Oslo: cordon pricing for the inner city area	Jenson (1999)	TRAM	Slight residential centralisation (+0.2%) and employment decentralisation (-0.5%); (all information from Whitehead, 2005)
Newcastle: Road user charge and access control	Bell et al. (2000)	CITIES	Concentration of population and jobs within restrained area, no magnitude reported; (all information from Whitehead, 2005)
London: Cordon pricing for inner city area	Centre for Economics and Business Research Ltd. (2001)	LTM/LRM	Modest increase in commercial rents and centralisation (+0.1 to 0.5%), residential impacts not studied; (all information from Whitehead, 2005)
Austin: motorway pricing 0.08 Euro/mile (2007-2012)	Gupta, Kalmanje, Kockelmann (2004)	DRAM-EMPAL/TransCAD	Slight increase (0 to 7%) of households and very slight increase (<1%) of employment in traffic zones near toll road corridors; overall no significant impact
Austin: area charging of 0.08 Euro/mile (2007-2012)	Gupta, Kalmanje, Kockelmann (2004)	DRAM-EMPAL/TransCAD	Jobs tend to spread to outer areas of Central Austin region (up to 2.2%)
Edinburgh: cordon pricing (double cordon) with fixed charge of 2.85 Euro	Transport Initiatives Edinburgh Ltd (2004)	DELTA/TRAM	Population levels predicted to be higher both within the city centre and at the fringe; employment levels are predicted to increase outside the city; some impacts on commercial rents though only very slight impacts in city centre; economic growth impact modest, if not imperceptible, prediction period unknown
Dortmund: cordon pricing for the inner city area of 6 Euro (2006-2030)	Spiekermann, Wegener (2005)	IRPUD	Increase of population within tolled area +1.6%, outer city area -1%,

[1]not stated if unknown
[2]maximum charge for non-regular trips

Table 3 Change of population and employment 10 years after introduction of cordon pricing modelled with land use and transport simulations (PROPOLIS results) [in %]

City name	Land use-transport interaction modelling package	Variable[1]	Cordon pricing effects with low charge (20min time value)				Cordon pricing effects with high charge (60min time value)			
			City centre	Inner urban	Outer urban	Rest of region	City centre	Inner urban	Outer urban	Rest of region
Bilbao	MEPLAN	P	7.1	5.4	5.5	5.9	10.2	5.5	4.9	5.7
		E	2.2	5.3	7.4	7.0	-1.2	5.8	8.7	8.2
Brussels	TRANUS	P	1.2	1.2	-2.1	0.0	3.3	3.4	-5.1	-0.2
		E	-2.2	-1.9	0.0	3.1	-2.7	-3.9	1.4	4.4
Dortmund	IRPUD	P	0.7	-0.8	-0.2	0.1	2.2	-0.8	-0.5	0.1
		E	-1.1	0.6	0.1	0.1	-1.2	-0.6	0.1	0.1
Helsinki	MEPLAN	P	4.1	2.8	1.6	-1.8	10.1	7.2	4.2	-3.4
		E	-0.7	-1.5	-1.0	1.0	-0.6	-1.9	-1.9	1.6
Inverness[2]	TRANUS	P	1.7	-0.9	3.7	3.5	3.5	-0.8	3.5	2.4
		E	-0.5	-0.8	1.8	0.3	0.3	-0.9	1.4	-0.2
Naples	MEPLAN	P	-4.7	-1.5	0.5	1.8	-7.5	-1.1	0.6	2.3
		E	-3.4	-0.3	0.9	1.9	-8.7	1.8	2.2	3.2
Venice	MEPLAN	P	-6.0	-0.9	-0.2	0.4	-8.8	-1.3	-0.5	0.7
		E	-13.9	1.7	0.8	0.8	-20.8	2.4	0.8	1.4

[1] P = population, E = employment

[2] for Inverness inner urban is zoned but not city centre; inner urban roughly equates to the city centre; the following categories in this application are “outer urban”, “rest of region urban” and “rest of region rural”

Source: Lautsi et al. (2004)